THE LIFE HISTORY OF *ATTACUS WARDI* ROTHSCHILD (LEPIDOPTERA : SATURNIIDAE) FROM THE NORTHERN TERRITORY, AUSTRALIA

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Abstract

The life history of *Attacus wardi* Rothschild is described from the Northern Territory, Australia, and discussion is presented on the species biology, distribution and potential distribution, based on available specimen records and the known foodplant distribution. The only known larval foodplant is *Croton habrophyllus* Airy Shaw (Euphorbiaceae). Comparisons are made between this species and *Attacus dohertyi* Rothschild, *Attacus intermedius* Jurriaanse & Lindemans, *Attacus inopinatus* Jurriaanse & Lindemans, *Attacus erebus* Fruhstorfer and *Attacus aurantiacus* Fruhstorfer, from Indonesia and East Timor. Some initial assessment is presented on the conservation status of *Attacus wardi*.

Introduction

The genus *Attacus* Linnaeus, 1767 belongs to the Tribe Attacini, Subfamily Saturniinae and includes most of the species popularly referred to as Atlas Moths, due to their large size, distinctive wing markings and broad wing area and shape. The genus is widely distributed throughout the Asian and Indian region, from the Himalayas, south through India to Sri Lanka, southern China, the south east Asian mainland, the Philippines, extending through Indonesia to northern Australia. Peigler (1989) in a revision of the genus *Attacus* lists fourteen species.

Attacus wardi Rothschild 1910 (Fig 15) is an Australian endemic and the only known *Attacus* species from northern Australia. It was first collected and recorded from the Northern Territory, Australia in February–May, 1909, when F.P. Dodd collected a number of cocoons of this species from "Port Darwin" (Peigler 1989). Dodd subsequently bred quite a number of specimens (about 50) from wild collected cocoons taken from "Port Darwin" and distributed most of these adult specimens to many of the world's museums and some private collections (Peigler 1989). Unfortunately no information was published or provided by Dodd on any life history or biological details of the species, although some notes on adult emergence times were reported by Dodd (in Oberthur 1916).

Since the first collection of the species in 1909-1910, the species remained completely unknown, with no further observations being made until a solitary adult male was collected at light by E.D. Edwards at Black Point, Cobourg Peninsula, Northern Territory in January, 1977 (E.D. Edwards pers. comm., Peigler 1989). Since 1977, no additional records or further observations were made, until some limited evidence was observed by or presented to the authors of the species' occurrence on Bathurst and Melville Islands,

(collectively known as the Tiwi Islands), N.T. during 2005, 2007 and 2008. The presence of the species was again confirmed on Melville Island during March, 2009, and March 2010, where adult moths, wild eggs, first, second, and third instar larvae, and pupal exuviae (empty cocoons) were found by the authors, and detailed observations were made of adult moth behaviour and of its early stages. During March 2010 the species was also found at Gunn Point near Darwin, where wild eggs were collected.

Attacus wardi was first described and subsequently recorded by other authors as a subspecies of *Attacus dohertyi* Rothschild 1895, viz *Attacus dohertyi wardi*, until a revision of the genus *Attacus* raised *wardi* to full species status (Peigler 1989). The distinctive life history of *Attacus wardi* described below confirms its full species status.

Life history

The known larval foodplant (Fig 14) *Croton habrophyllus* Airy Shaw (Euphorbiaceae) is a tree that is endemic to Western Australia and the Northern Territory (Hyland & Whiffin 1993), and grows to a height of 8-10 metres within monsoon forest areas and fringing forest areas along watercourses, from sea level to approximately 100 metres elevation. Trees of between 3-7 metres in height and growing either along the outer margins of, or along transect tracks through the monsoon forests appeared to be particularly favoured by ovipositing females of *A. wardi*. It is believed that such situations provided adequate flight space for the large female moths - however these observations may more reflect the authors' observational techniques, as many of the crowns of tall *Croton* trees growing within the monsoon forest areas were more difficult to adequately access. In fact it is likely that the upper crowns of tall Croton trees are the favoured oviposition sites of the moths, as typical larval feeding patterns within the upper canopy were regularly observed from the ground. All wild eggs found had been laid in the upper crown of foodplant trees on the underside of mature leaves.

Egg (Fig 1). Oval, flattened type, approx 2.6x2.1x1.6mm high, pale brownish white, laid singly or in a line of two, three or four adjacent but separated by several millimetres on the underside of the foodplant leaf, lying near to the leaf margin and usually no further than 1cm from the leaf margin. Eggs have a coating of a pale brown secretion which appears to be an adhesive agent for affixing the eggs to the leaf surface. Wild *A. wardi* eggs were observed to have an incubation period of at least 10 - 15 days.

First instar larva (Figs 2-3). Length 5-10mm. Head, prolegs, thoracic and abdominal segments all jet black. Each segment carries six long fleshy, erect scoli, two dorsal, one subdorsal each side, one scoli below spiracles, all jet black. All scoli carry a series of radial black spines at apex. Larval duration 4-5 days.

Second instar larva (Figs 3-4). Length 10-16mm. Head and thoracic legs light brown. Prolegs, thoracic and abdominal segments white, but with mixed pale brown intermittent spotting. Erect scoli much longer than those of first instar, equally fleshy, all coloured white with apex of scoli adorned with a ring of white "cotton wool" like fleshy appendages and short white radial setae. Scoli on anal segments shorter than those on abdominal segments. Anal prolegs white. Abdominal segments 1&2, 7&8 each with a lateral red area that lies between the subdorsal scoli and the scoli below the spiracles. Thoracic and abdominal segments are lightly coated in a fine whitish powder. Larval duration 7-8 days.

Third instar larva (Fig 5). Length 16-37mm. Head and thoracic legs light brown. Prolegs, thoracic and abdominal segments all white, but adorned with intermittent dark green spotting. Long fleshy scoli coloured white, adorned at apex as in second instar larva with "cotton wool" like fleshy appendages and short white setae – those on abdominal segments sloping backwards. Thoracic and abdominal segments covered with a white wax-like powder which can be easily dislodged if the larva is touched or handled in any way. Anal prolegs same colour as prolegs and body, but shows the first discernable sign of a "false eyespot" lateral marking. Prolegs each with a series of short white basal setae. Larval duration 9-10 days.

Fourth instar larva (Figs 6-8). Length 37-60mm. Head and thoracic legs pale greenish white. Prolegs, thoracic and abdominal segments all white but adorned with intermittent dark green spotting; spotting is larger and more distinctive on abdominal segment 8 and anal prolegs. Scoli long and fleshy, much thinner than those of third instar, coloured white but with upper half pale blue – (this blue colouring is less pronounced in early fourth instar larvae), becoming darker after two days. Scoli with short white setae arising from various lengths along the scoli stem. Scoli on abdominal segments sloping backwards as in third instar. Spiracles very pale blue, ringed white. Larval body carries patches of white wax-like powder, but in lesser quantity than that of third instar. Anal prolegs adorned with a black lateral "false eyespot", lightly pitted. Scoli on anal segments greatly reduced, three dorsal rows of low domed shape, and coloured light blue; an anterior row of 4, with two lower parallel posterior rows comprising 2 scoli each. These scoli represent the morphological change to defensive glands, as also recorded for *A. dohertyi* (Paukstadt & Paukstadt 1993), however their function as such could not be determined. Larval duration 12-13 days.

Fifth instar larva (Figs 9-10). Length 60-85mm. Head, thoracic legs, prolegs, and body segments all light green, closely matching the colouration of the foodplant leaves. Dark green intermittent spotting faintly indicated on thoracic segments, but more pronounced on abdominal segment 8 and anal prolegs. Long thin scoli light green at base, white mid section, with dark blue upper one third; those on abdominal segments sloping backwards as in fourth

Figs 1-7. *Attacus wardi*: (1) egg; (2) first instar larva; (3) first & second instar larva; (4) second instar larva; (5) third instar larva; (6) early fourth instar larva; (7) fourth instar larva, lateral view.

instar; each white and dark blue scoli section is also adorned with short white and blue setae respectively. Some small amounts of white waxlike powder present in the "folds" at segmental junctions. Spiracles coloured as on body, ringed lighter green. Anal prolegs with black "false eyespot" lightly pitted. Eight much reduced, low dome shaped scoli on anal segments coloured darker green, representing defensive glands but their functionality was not confirmed. The larval body is large and bulky. Larval duration 11-12 days.

Sixth instar larva (Figs 11-13). Length 85-115mm. Very similar to fifth instar, but more bulky. Scoli of similar colour to fifth instar, but shorter in length. No visible defensive gland scoli on anal segments. Intermittent dark green spotting not distinct, and only present on abdominal segment 8 and anal prolegs. Larval duration 8-9 days.

Pupa and cocoon (Figs 16-17, 18-19). Pupa dark brown, approaching black, stout and ovoid in shape, length 32-38mm, width 18-22mm at wingcases. Male antennal covers much broader than female. Hindwing wing cases extend past that of the forewing. Cremaster blunt, rounded. The only available (to the authors) pupae for comparison are those of *Attacus erebus* Fruhstorfer from Sulawesi, Indonesia (DAL coll., legacy S. Naumann, Germany) – the pupa of *erebus* is slightly larger than but similar in shape to that of *wardi*, and light brown in colour. The pupa of *A. dohertyi* is brown, whilst that of *A. inopinatus* is red brown (Paukstadt & Paukstadt 1993,1992).

The location of wild observed cocoons of *A. wardi* indicate that in some situations mature larvae leave the foodplant tree canopy to reach lower sections of the tree, or leave the tree to reach intertwining vines or understorey shrubs, on which to pupate. Cocoons are cylindrical or broadly cylindrical, elongated, tapering at each end, 60-90mm in length, 25-40mm wide at the midsection, are of double walled construction, and have either a single or several leaves wrapped around the outer cocoon, all tightly attached with silk, which serves to camouflage the cocoon to a remarkable extent; the impression is one of a dead hanging leaf. The leaf stalk and adjacent stem is also wrapped in silk, effectively securing the cocoon from falling away. Colour of cocoons ranges from light tan to coffee brown, and is slightly darker than that of *A. erebus*. During the final process of pupation, *A. wardi* larvae, once suitably enclosed by their newly spun white silken cocoon, and also housed by the wrap-around leaf, appear to regurgitate a brown liquid which initially saturates the cocoon walls, with some excess brown liquid dripping and falling away from the cocoon. This process gives the cocoon its distinct tan or coffee brown colour. Its purpose is not clearly understood, but it is believed that it acts as a drying and sealing agent to protect the inner pupa from fungal, bacterial or viral infections, and possibly dessication. Adult moths have been observed to emerge from their cocoons after intervals of 21 -30 days, or the cocoons may enter diapause for periods of up to twelve months.

Dodd, in his 1916 recorded observations of his trip to Port Darwin in 1909-1910, when referring to the cocoons that were collected, stated "Most of these emerged within three months time, some up to six months after our return to Kuranda, but the last one duly emerged after remaining in pupa for over 14 months."

Biological observations

Of numerous eggs found in the wild, quite a few were found to be parasitised by a minute species of wasp (*Agiommatus sp.*, Superfamily Chacidoidea, Family Pteromalidae, Subfamily Pteromalinae. (identification John La Salle, E.D. Edwards, pers. comm., specimens deposited in ANIC)). Species of wasp from this genus have been recorded parasitising moth eggs in *Antheraea* (Saturniidae), *Acherontia* (Sphingidae) and those of skippers belonging to *Erionata* (Hesperiidae). The genus is distributed in Africa (including Madagascar), South Asia to Australia (E.D. Edwards, pers. comm.). This minute species of *Agiommatus* appears to be a primary population control agent of *A. wardi,* and by our observations approximately 35% of wild eggs had been parasitised. Each parasitised egg had only a single adult wasp emerge, executed by cutting a minute exit hole through the egg wall.

First instar larvae appear to be fairly tenuous of life – they first devour the greater part of the hatched eggshell, leaving only a basal plate or part of the wall. A period of inactivity of 4 – 12 hours then follows, with those larvae remaining motionless on the leaf underside, usually near to the remnant eggshell. Two such first instar larvae did not begin to feed, and perished – however after this inactive period all others began to feed by cutting irregular patches from the leaf margin of semi juvenile leaves. By second instar, larvae wander and become widely dispersed through the upper tree.

Larval development through the six instars is over 51-56 days, and all instars displayed periods of continuous feeding followed by equal periods of inactivity of up to several hours. Apart from short periods of moving around the foodplant tree to seek fresh feeding areas, larvae of all instars mostly remained on the underside of the foodplant leaves, or in the case of fifth and sixth instar individuals, sometimes upside down on small twigs. Second to sixth instar larvae displayed a high degree of protective camouflage amongst their foodplant leaves. First instar larvae generally resembled brown or blackish leaf blemishes that were a feature of mature foodplant leaves, and were equally well camouflaged.

On Melville Island adult moths are often taken by Boobook Owls *(Ninox novaeseelandiae)* after they have been attracted to street lights. Here the birds appear to patrol around certain street lights, awaiting the arrival of any large bodied moths. Our observations of the regular assemblage of remnant moth wings including *Attacus* on the ground below certain street lights was testament to the birds' activity. Green Tree Ants (*Oecophylla smaragdina* (Fabricus, 1775)) are known to prey upon saturniid larvae in general

(DAL pers obs). Foodplant trees with any Green Tree Ant activity never contained eggs or larvae of *A. wardi*.

While our field observations were conducted over a brief time interval during March 2009 and March-April 2010, and to date the only confirmed foodplant is *C. habrophyllus*, there is a strong probability that other foodplant trees would be utilised, particularly other plants belonging to Euphorbiaceae. *Croton tomentellus* F. Muell. grows in similar situations to *C. habrophyllus*, though it is a slightly smaller tree in height, and also has a slightly wider distribution, extending from Western Australia to the Northern Territory, through to north east Queensland (Hyland & Whiffin 1993). *Omolanthus novo-guineensis* (Warb.) Lauterb. & Schumann (Euphorbiaceae) also has a similar distribution and habitat to both above *Croton* species, ranging from Western Australia through to north east Queensland (Hyland & Whiffin). A number of larvae of all instars of *A. wardi* were offered *O. novo-guineensis* as food, and readily accepted this and developed at a comparable rate to those on *C. habrophyllus*.

Discussion

Some Australian, Indonesian and Papuan species of Saturniidae are quite sedentary; adults are not often observed, in cases due to extremely localised distributions, extremely short flight periods that may be directly tied with seasonal rainfall or relative humidity, and relatively short adult lifespans (estimated 3-5 days, DAL pers. obs.). Nocturnal flight periods may be either late evening or early morning. *Attacus wardi* appears to fit very well into this category, and its flight periods, biology and sedentary behaviour can be directly compared with *Attacus dohertyi* from Timor (DAL, pers. obs.). Available records of adult *A. wardi* emergences (including from Dodd's original material, Peigler 1989) list the months of January to February, extending to early March. Our observations of wild adult moths confirm a nocturnal period of flight activity between 23.00 – 03.00 hours, and combined with observations of some Tiwi Islands residents, also confirm early to late March as the flight season, provided good monsoonal rainfall occurs. Our observations of eggs, first, second and third instar larvae, and empty cocoons in late March, gives further credence to March being part of the flight season of *A. wardi*.

Of historical interest, during 1935 Walter Dodd published a series of newspaper articles titled "Meanderings of a Naturalist" in the "North Queensland Register" published out of Townsville (G. Monteith, pers comm). In one such article dated 9 March 1935, Walter describes the trip to Darwin with his father in 1908, and when referring to *A. wardi* states "We had many pupae, and whilst the moths were emerging, males of the species were occasionally attracted from the jungle several miles away".

Observations of the flight activity of *A. dohertyi* in East Timor (DAL & M. Lane, 2002 & 2004) confirmed that adult emergence is triggered by the first

substantial wet season rainfall. After good rainfall in October 2002 that followed several months of little to no rainfall, a significant number of adult moths were collected at lights at Bobonaro for a period of about one week (always between 2300 – 0300 hrs), but then populations quickly tapered and no further adult activity was observed.

Comparisons

Peigler (1989) lists the characteristics that clearly separate adults of *A. wardi* from those of three geographically adjacent and closely related species, viz *A. dohertyi* (Timor, Romang and Damar Is. (Lesser Sunda Islands)), *A. intermedius* (Tanimbar Islands), and *A. inopinatus* (Flores (Lesser Sunda Islands)). Paukstadt & Paukstadt (1992 & 1993) described and illustrated the life histories of *A. inopinatus* and *A. dohertyi* with black and white photographs. Peigler & Wang (1996) documented in colour photographs the life history of *A. dohertyi*. Peigler (1989) stated that *A. intermedius* was so named because its authors intended to convey the point that this moth appears intermediate between *A. dohertyi* and *A. wardi*, believing that all three species were conspecific. The life history of *A. intermedius* remains unknown.

All larval instars of *A. wardi* are readily distinguished from those of both *A. dohertyi* and *A. inopinatus*. Firstly the jet black colouration of the first instar larva of *A. wardi* is unique amongst all known species of *Attacus*, and is quite unlike the first instar larva of either *dohertyi* or *inopinatus*, which are both coloured white with some degree of black striping. Compared with those of *dohertyi*, the second, third, fourth and fifth instar larvae of *wardi* show noticeable differences in colour, shape and form of scoli, prolegs, thoracic and abdominal segments. The sixth instar larva of *wardi* is closer to that of *dohertyi*, but differs from that species in the extent of upper blue scoli colouration. Second to sixth larval instars of *inopinatus* differ considerably from those of both *wardi* and *dohertyi*, particularly in shape, length and colouration of scoli, and also in colouration of prolegs, thoracic and abdominal segments. The final instar larva of *Attacus aurantiacus* Fruhstorfer (Nassig & Taschner, 1996) from the Kai Islands, Indonesia differs significantly from all of the above species, with dorsal and lateral scoli coloured bright red and dark blue. Based on sixth instar larval characters, *A. wardi* appears to have a closer affinity to *A. dohertyi* than to all other species, and possibly displays close ancestral ties with *dohertyi*.

Distribution and conservation status

To date, *Attacus wardi* has remained a poorly known and understood species in terms of its known distribution, flight times, range of foodplant preferences, and its specific habitat requirements. Our observations, combined with historic records, indicate that the species is restricted to the monsoon forest areas of the northern coastal areas of the Northern Territory, including but not limited to Darwin, Gunn Point, the Tiwi Islands, and

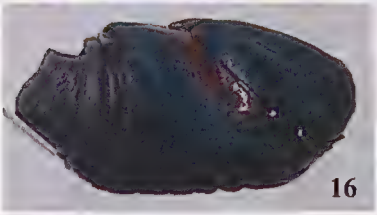
Figs 8-13. *Attacus wardi*: (8) fourth instar larva, dorsal view; (9) fifth instar larva, lateral view; (10) fifth instar larva, dorsal view; (11) sixth instar larva; (12) sixth instar larva, frontal view; (13) sixth instar larva, rear segments & anal claspers.

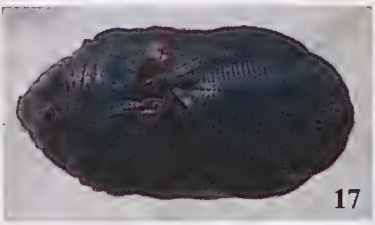
Cobourg Peninsula (Garig Gunak Barlu National Park), and adults principally fly during the wet season months (January to March). Local adult population numbers can be quite high but for extremely limited duration, and like its counterpart *A. dohertyi*, adult nocturnal flight activity is limited from the late evening to early morning. However, should good summer storms provide suitable conditions, it is also quite feasible that an earlier generation of *A. wardi* might occur around October to December. Based on the published distributional data of *Croton habrophyllus* as a known foodplant source, and combined with the seasonal rainfall distribution of the Northern Territory, *A. wardi* may occur as far east as Nhulunbuy and Groote Eylandt, as well as the many intervening coastal monsoon forest areas, where extensive areas of suitable habitat remain. It is our belief that several other foodplant tree species from several plant families will be found to be used by *A. wardi*, as is the case with other species of *Attacus* (Peigler 1989), and also other closely related genera, such as *Coscinocera* Butler (DAL pers. obs., Common 1990).

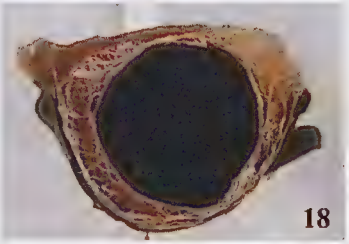
Peigler (1989), under material examined, lists two male specimens of *A. wardi* held in the American Museum of Natural History (AMNH), New York, that carry data labels citing "Cape York" and "North Cape York Peninsula" in Queensland as localities. These localities are considered most unlikely by the authors, as the zoogeographic region of Cape York Peninsula is considered far more closely aligned with the Papuan/Australian faunal area than that of Indonesia. However, a close lookout should still be maintained by entomologists particularly those visiting the north western coastline of Cape York. Peigler (1989) also considered *Coscinocera hercules* Miskin to be sympatric with *A. wardi* at Darwin – this is incorrect as within Australia *C. hercules* is restricted to north eastern Queensland.

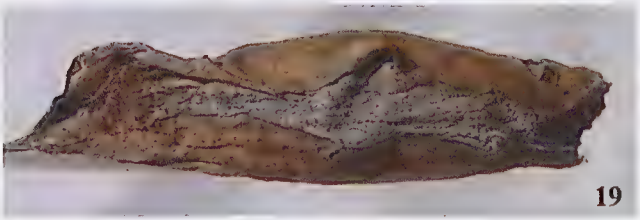
The forest verges of the 'Top End' are a constantly changing interface, where pioneer trees including *Croton* species are a component of an ever expanding or contracting monsoon forest, dependant on rainfall intensity and seasonality, combined with the frequency and intensity of fire regimes. It is our opinion that any component of irregular or frequent fires that penetrate the monsoon forest verges would be severely destructive to populations of *A. wardi.* The observed tendency for mature larvae to form their cocoons on mid to lower parts of the foodplant trees, or on understorey shrubs, would leave them extremely vulnerable to any fire activity, especially as the species undergoes dry season diapause as a pupa.

The observed habit of some mature *A. wardi* larvae leaving the upper forest canopy to pupate at lower levels may be an adaptation to having developed some degree of protection against high cyclonic winds. It is of particular interest to compare this behaviour with that of several north Queensland species of moth, whose specific habitat is periodically exposed to cyclonic disturbance. The observed larval habits of leaving their feeding zones in the forest canopy and forming cocoons on lower sections of their foodplant trees,









Figs 14-19: *Attacus wardi*: (14) foodplant tree, *Croton habrophyllus*; (15) adult female, ex pupa; (16) male pupa, lateral view; (17) male pupa, ventral view; (18) cocoon, cross sectional view, depicting double walled construction; (19) cocoon.

or on understory trees or shrubs, may well be an adaptation to avoiding the high canopy winds of infrequent cyclones. In particular, three large moth species that exhibit this behaviour are *C. hercules*, the uraniid moth *Alcides metaurus* (Hopffer), and the anthelid moth *Chelepteryx chalepteryx* (R. Felder). The latter species feeds as a larva within the forest canopy of the tall wet sclerophyll and rainforest areas at high altitude on the southern and western Atherton Tablelands. In this situation mature larvae lower themselves onto understorey shrubs and trees to spin their cocoons (DAL pers. obs.), whereby the large heavy pupae appear to gain some protection from high winds.

In the Northern Territory some introduced plant and insect pest species may prove to be of concern to populations of *A. wardi* – Gamba grass (*Andropogon gayanus* Kunth.) is spreading across the 'Top End', and burns fiercely and hot, potentially providing a threat to the monsoon forest verges and their extent. The introduced Yellow Crazy Ant (*Anoplolepis gracilipes* (Fr. Smith)) occurs in the East Arnhem region near Gove, and colonies of this ant are notorious for destructively devouring all available food resources in the near vicinity.

The habitat requirements of *A. wardi* as observed at Gunn Point and Melville Island are reasonable sized pockets of Monsoon Forest, of a possible minimum size of around 8 hectares but preferably up to 20 hectares or larger, containing good numbers of *Croton* foodplant trees. The pockets should stand in reasonably close proximity to each other, so that adult moths can intersperse readily between them. The greater the number of such Monsoon Forest pockets, combined with their near proximity to each other, the more the secure are *A. wardi* populations inhabiting them.

Historic maps of Darwin and environs suggest that at one time extensive bands of Monsoon Forest extended almost continuously from the Darwin Esplanade, through East Point, to Nightcliff, Casuarina and Lee Point. It is our opinion that this band of Monsoon forest was the locality from which Dodd's 1909 historic specimens were collected. Sadly the greater part of this habitat is now gone, with the remaining remnant Monsoon Forest now found only at East Point and Lee Point. Interestingly, at both of these sites a number of large and small *Croton* trees are well established, but our searches have so far failed to find early stages of *A. wardi*. These areas in theory are indeed suitable habitats, but we feel that they are currently too isolated from each other, without intervening pockets, and hence are too small to support a viable population of *A. wardi*. However, should a suitable replanting programme ever be instigated, to interconnect these remnant pockets with suitable intervening Monsoon Forest pockets containing adequate *Croton* and other Euphorbiaceae trees, then the opportunity may then arise to re-introduce *A. wardi* to the Darwin coastal area.

At present, the conservation status of *A. wardi* seems fairly secure, with good populations known from the Tiwi Islands and Gunn Point, coupled with adult records from Cobourg Peninsula (Garig Gunag Barlu National Park). Populations are almost certain to be found at intermediate localities between Gunn Point and Cobourg Peninsula where extensive habitat remains, and possibly through to the Nhulunbuy area. The protected species status of *A. wardi* does not appear justified, particularly as such little research has been undertaken on its biology and habitat requirements. A conservation status listing as Data Deficient would be more appropriate – with a recommendation that much more detailed research be undertaken into the species biology and distribution. Habitat protection is far more relevant to the long term tenure of *A. wardi*, particularly in consideration of the current extremely poor management of fire regimes across the 'Top End'.

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